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ORTHOPAEDIC SURGERY

Incidence and prognostic factors for postoperative frozen shoulder after shoulder surgery: a prospective cohort study

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Abstract
Purpose Frozen shoulder is a potential complication after shoulder surgery. It is a clinical condition that is often associated with marked disability and can have a profound effect on the patient's quality of life. The incidence, etiology, pathology and prognostic factors of postoperative frozen shoulder after shoulder surgery are not known. The purpose of this explorative study was to determine the incidence of postoperative frozen shoulder after various operative shoulder procedures. A second aim was to identify prognostic factors for postoperative frozen shoulder after shoulder surgery.
Methods 505 consecutive patients undergoing elective shoulder surgery were included in this prospective cohort study. Follow-up was 6 months after surgery. A prediction model was developed to identify prognostic factors for postoperative frozen shoulder after shoulder surgery using the TRIPOD guidelines. We nominated five potential predictors: gender, diabetes mellitus, type of physiotherapy, arthroscopic surgery and DASH score.
Results Frozen shoulder was identified in 11% of the patients after shoulder surgery and was more common in females (15%) than in males (8%). Frozen shoulder was encountered after all types of operative procedures. A prediction model based on four variables (diabetes mellitus, specialized shoulder physiotherapy, arthroscopic surgery and DASH score) discriminated reasonably well with an AUC of 0.712.
Conclusions Postoperative frozen shoulder is a serious complication after shoulder surgery, with an incidence of 11%. Four prognostic factors were identified for postoperative frozen shoulder: diabetes mellitus, arthroscopic surgery, specialized shoulder physiotherapy and DASH score. The combination of these four variables provided a prediction rule for postoperative frozen shoulder with reasonable fit.
Level of evidence Level II, prospective cohort study.

Keywords Incidence · Prognostic factors · Postoperative frozen shoulder · Shoulder surgery

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Introduction

Shoulder stiffness is a complication which negatively affects clinical outcome after shoulder surgery. In orthopedic literature many different causes and definitions of postoperative stiffness are reported [1–4]. Postoperative stiffness may be the consequence of scarring triggered by the surgical intervention and postoperative immobilization, but also the development of postoperative frozen shoulder is described with inflammation of the capsule of still

unknown etiology [1, 5–8]. Postoperative frozen shoulder is a clinical condition that is often associated with marked disability and can have a profound effect on the patient's quality of life [6]. Typically postoperative frozen shoulder presents after an initially successful postoperative rehabilitation process, but then is followed by a worsening of pain in the shoulder with gradual loss of both active and passive range of motion [8]. Differentiation of patients with postoperative frozen shoulder from patients with other causes of postoperative stiffness is clinically important because the clinical course and the treatment is different. Frozen shoulder has a benign natural course in most patients [6, 9]. In other types of shoulder stiffness after shoulder surgery, for example if scar tissue or a contracture of the rotator cuff or capsular/ligaments structures of the shoulder is the cause of pain and stiffness, pain and stiffness will persist if left untreated [10–12]. Patients with frozen shoulder need to be treated differently than other patients with postoperative stiffness [8]. When frozen shoulder develops after surgery, rehabilitation should be modified with analgesia and activity modification [6, 8, 13]. Conversely, if scar tissue or a contracture of the rotator cuff or capsular/ligaments structures of the shoulder is the cause of pain and stiffness after surgery, then aggressive physical therapy or an operative capsular release is indicated [10–12].

Previous reports have studied postoperative stiffness after rotator cuff repair, but they did not differentiate between secondary frozen shoulder and other causes of stiffness. In a recent study, Evans et al. was the first who identified the incidence of frozen shoulder after two shoulder procedures: arthroscopic subacromial decompression and arthroscopic acromioclavicular joint excision [8]. We are unaware of previous studies that have analyzed secondary frozen shoulder following other operative shoulder procedures. The incidence, etiology and pathology and prognostic factors of secondary frozen shoulder after shoulder surgery are not known. When frozen shoulder after shoulder surgery can be predicted, shoulder surgeons and physiotherapists might modify treatment in high-risk patients and patients can be informed about their risk of developing frozen shoulder after surgery.

The purpose of this explorative study was to determine the incidence of postoperative frozen shoulder after various operative shoulder procedures. A second aim was to identify prognostic factors for postoperative frozen shoulder after shoulder surgery.

Patients and methods

We used a prospective cohort design to study the incidence of secondary frozen shoulder after elective operative shoulder procedures. A prediction model was developed to identify prognostic factors for postoperative frozen shoulder after shoulder surgery.

We included all consecutive patients that were planned for elective shoulder surgery in a 4-year period (1-1-2009 till 31-12-2013). Inclusion criteria included: (1) presenting for a planned elective shoulder surgery; (2) at least 16 years of age; (3) be able to complete questionnaires. Exclusion criteria included: (1) frozen shoulder before surgery; (2) fracture/nonunion or malunion; (3) stiffness caused by glenohumeral osteoarthritis (including shoulder arthroplasty); (4) shoulder arthrodesis; (5) diagnostic shoulder arthroscopy; (6) preoperative or postoperative neurological disorder or complication (e.g., stroke, Parkinson's disease); (7) postoperative deep infection.

Elective shoulder surgery Surgeries were performed in a general teaching hospital with a shoulder subunit. All surgeries were performed by a single surgeon or by one of his supervised residents. All patients received standard guidance from a shoulder physiotherapist immediately after surgery and all were referred to a community physiotherapist. Physiotherapy at home was started within 1 week after surgery. Although patients were free to choose any community physiotherapist, we advised patients to choose a specialized physiotherapist from our Regional Shoulder Network. The Regional Network of Shoulder Physiotherapists is a network with 25 specialized, trained shoulder physiotherapists. These physiotherapists were extensively trained to treat shoulder surgery patients. The shoulder physiotherapists were instructed to look for signs of postoperative frozen shoulder. If frozen shoulder developed, the physiotherapist modified the rehabilitation program to include more rest and to restrict mobilization of the capsule. Standardized rehabilitation protocols and guidelines for mobilization were used. After rotator cuff repair the shoulder was immobilized for 6 weeks, allowing daily passive range of motion and pendulum exercises. After a stabilizing procedure the shoulder was immobilized for 3 weeks with daily active guided exercises, and after all other operations the shoulder was immobilized for 2–3 days with immediate active exercise.

Outcome measure

For the definition of postoperative frozen shoulder we used the definition by Evans et al. [8], and completed the definition with the consensus definition of the British Shoulder and Elbow Society of frozen shoulder [14]:

1 an initially successful postoperative rehabilitation process after shoulder surgery is followed by worsening pain in the shoulder with gradual loss of both active and passive range of motion

2 symptoms of true (deltoid insertion) shoulder pain and night pain of insidious onset
3 painful restriction of active and passive movement, with passive movement limited to <100° elevation, <30° external rotation and internal rotation limited to L5 or less.

The Constant–Murley score (CMS) is a 100-point scale divided into four subscales: pain (15 points), activities of daily living (20 points), strength (25 points) and range of motion (40 points) [15]. The Disabilities of the Arm, Shoulder and Hand (DASH) Questionnaire is a 30-item, self-report questionnaire designed to measure physical function and symptoms in people with any of several musculoskeletal disorders of the upper limb [16]. The Four-Dimensional Symptom Questionnaire (4DSQ) is a 50-item self-report psychological questionnaire, validated for orthopedic shoulder patients, that identifies four common psychological symptoms: distress, depression, anxiety, and somatization [17, 18].

Data collection

Male and female patients who presented at the orthopedic clinic and were planned for elective shoulder surgery were screened for eligibility. Eligible patients, after giving their consent, were seen at an outpatient clinic by a physiotherapist from our shoulder unit 2–3 weeks before elective shoulder surgery. The physiotherapist was an independent researcher not involved in the treatment of these patients. Patients were examined following a standard protocol, demographic and clinical variables were collected. Standard radiography of the shoulder was taken for each patient before surgery, an MRI or CT-scan was performed in most patients. All patients were screened for the presence of frozen shoulder before surgery, using the consensus definition of the British Shoulder and Elbow Society, by the physiotherapist and also by the surgeon under anesthetic immediately before shoulder surgery. During arthroscopic surgery the capsule was checked for vascular granulation tissue, suggestive of frozen shoulder.

Patients were evaluated 6 weeks, 3 months and 6 months after the operation. At 6 weeks patients were examined by an experienced shoulder physiotherapist and at 3 and 6 months by the operating surgeon. All patients were postoperatively examined according to a standard protocol, including the range of motion of the operated shoulder and the contralateral shoulder. Range of motion was measured with the patient lying supine and standing, using a standard 30-cm goniometer. Elevation and abduction were scored by measuring the angle formed by the arm and thorax. External rotation was determined with the arm adducted and the elbow at the side and flexed to 90°. Internal rotation of the arm behind the back was evaluated by the vertebral level that could be reached by the dorsum of the hand.

Data analysis

The aim of this study was to identify prognostic factors for postoperative frozen shoulder after shoulder surgery. For the statistical analysis we followed the recommendations by Herbert [19]: cohort studies can answer questions about etiology (causation) or prognosis (prediction). Depending on whether generating information about etiology or prognosis is the topic of the study, it should have quite different design and analysis. To identify prognostic factors a prediction model was recommended. A prediction model was developed using the TRIPOD guidelines [20]. According to the recommendation by Peduzzi, we selected one candidate predictor for every ten cases [21]. Before conducting the analysis, we nominated five potential predictors based on the results in the baseline table, expert knowledge and previous literature: gender, diabetes mellitus, type of physiotherapy, arthroscopic surgery and DASH score. We selected gender and diabetes as potential prognostic factor because in literature frozen shoulder is more frequently encountered in females and in patients with diabetes. We decided to examine if specialized shoulder physiotherapy compared to regular physiotherapy is a prognostic factor for the development of frozen shoulder, because in our clinical practice we had the clinical impression that frozen shoulder was less frequently encountered when the patient was treated by a specialized shoulder physiotherapist after surgery. Literature indicates that postoperative stiffness is more often seen after open surgery compared to arthroscopic surgery. We are not aware of any publication that studied if postoperative frozen shoulder is more frequently observed after open surgery. Therefore, we decided to choose this as a potential prognostic factor. Severity of shoulder symptoms might be associated with the development of frozen shoulder after surgery. The DASH score was selected as a potential prognostic factor. Of these predictors only the DASH score was treated as continuous variable and the linear association with the outcome variable was checked.

A backward selection strategy by hand in the full, five-predictor model was performed to select predictors for the final model. Predictors were deleted step by step from the model based on the highest p value. To adjust for overoptimism, 500 bootstraps were performed to adjust the 95% confidence intervals around the regression coefficients. Bias-corrected and accelerated (BCa) 95% CI are reported. Then, goodness of fit was evaluated by inspecting calibration plots [22] and with the Hosmer–Lemeshow test [23]. Next, prediction scores were calculated using the formula $P = \exp(\ln(\text{odds}))/(1 + \exp(\ln(\text{odds})))$. Calculated predictions were used to evaluate the discriminative power of the model by inspecting histograms of prediction scores and the c index (i.e., the area under the receiver

operating characteristic curve). SPSS statistical software (version 20.0; IBM, Armonk, NY, USA) was used for data compilation and statistical analyses. A p value of <0.05 was considered statistically significant.

Results

Flow of participants through the study

Figure 1 shows a summary of the participants' flow; 505 patients where included in the present analysis. In 8 patients both shoulders were operated during the study period, only the first shoulder operation was analyzed. There was a high rate of follow-up (90%). In the study period 58 patients (10%) did not attend their final postoperative assessment 6 months after surgery and were therefore lost to follow-up. We analyzed the baseline characteristics of these 58 patients and compared them with the patients of the study population. Type of operation ($p = 0.000$), age ($p = 0.020$) and gender ($p = 0.003$) were statistically significantly different between the groups. The majority of patients who did not attend our outpatient clinic 6 months postoperatively were patients who had an arthroscopic subacromial decompression or an excision of a calcific deposit in the rotator cuff. The predominance of

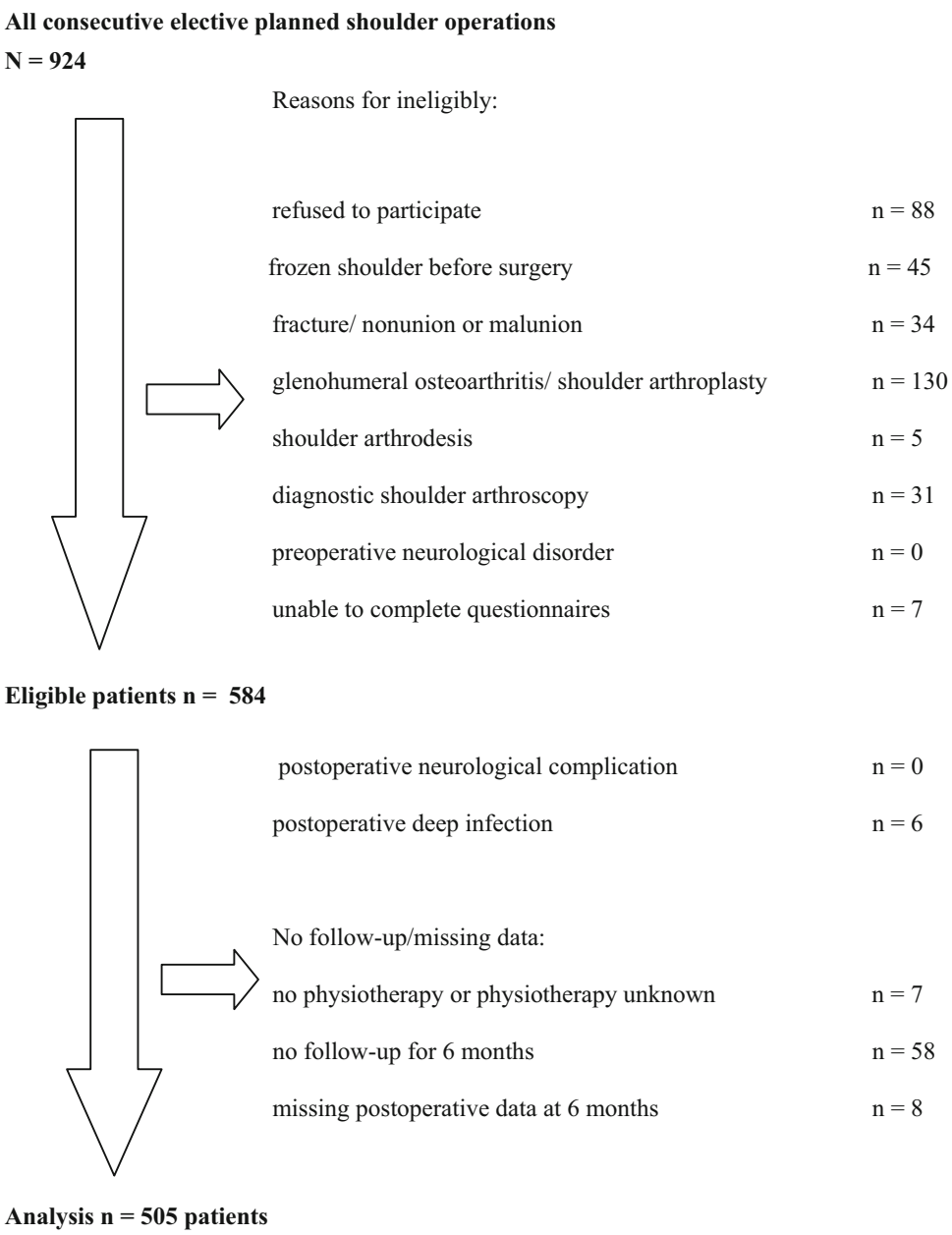

Fig. 1 Summary of participants' flow in this prospective cohort study

these two operations explained why the mean age and gender distribution were different in this group than in the study population. Eight patients did have a clinical follow-up 6 months after surgery but some clinical data from this follow-up visit were lost, hence these patients were also excluded.

Incidence of postoperative frozen shoulder after shoulder surgery

Postoperative frozen shoulder was observed in 11% of the patients: 8% in males and 15% in females ($p = 0.01$ (1.42–12.8). Secondary frozen shoulder was encountered in all different shoulder procedures: 12% after subacromial decompression, 8% after rotator cuff repair, 12% after stabilizing procedures, 12% after distal clavicle resection, 12% after excision of calcific deposit and 15% after other shoulder procedures. Baseline characteristics of patients with and without postoperative frozen shoulder after shoulder surgery are given in Table 1.

Prediction of postoperative frozen shoulder after shoulder surgery

Four of the five potential predictor variables (all except arthroscopic surgery) had statistically significant univariate relationship with risk of frozen shoulder (Table 2). Arthroscopic surgery, although statistically not significant, was considered to be clinical relevant and was therefore selected as an additional candidate variable for the prediction model. All candidate variables (gender, diabetes mellitus, specialized shoulder physiotherapy, DASH score and arthroscopic surgery) were considered for inclusion in a logistic model. The manual backward selection procedure identified a prediction model for postoperative capsulitis including four predictors: diabetes mellitus, specialized shoulder physiotherapy, DASH score and arthroscopic surgery. Arthroscopic surgery did not gain statistical significance in the univariate analysis but appeared to be of additional value in the final prediction model, achieving the highest discriminative ability. Table 3 presents the odds ratio and bootstrapped 95% CI of the model. The Hosmer–Lemeshow test was not statistically significant, indicating no evidence of a failure of model fit. When individual prediction was calculated from the regression formula, a ROC curve was generated. The prediction model had reasonable discriminative ability with an AUC of 0,712. In Fig. 2, the patients were grouped into the postoperative frozen shoulder group and into the no postoperative frozen shoulder group; then we plotted the estimated probabilities of a postoperative frozen shoulder, according to the prediction model. According to our prediction model, the median probability of a postoperative frozen shoulder was 15% in the postoperative frozen shoulder group and 8% in the no postoperative frozen shoulder group.

Discussion

Frozen shoulder is a common and clinically relevant complication after shoulder surgery, with an incidence of 11%. This study prospectively monitored a cohort of 505 consecutive cases after elective shoulder surgery with a follow-up rate of 90%. We developed a prediction model and identified four prognostic factors: diabetes mellitus, arthroscopic surgery, specialized shoulder physiotherapy and DASH score. We observed that the combination of these four variables provided a prediction rule for postoperative frozen shoulder with reasonable fit.

No previous prediction models to identify prognostic factors and predict the development of postoperative frozen shoulder after shoulder surgery were found in literature. In the retrospective study by Evans et al. [8] prognostic risk factors for the development of secondary frozen shoulder after two arthroscopic shoulder procedures were age (between 46 and 60 years) and a previous idiopathic contra lateral frozen shoulder. In our study, we identified four prognostic factors: diabetes mellitus, arthroscopic surgery, specialized shoulder physiotherapy and DASH score. One of the prognostic factors for the development of postoperative frozen shoulder was arthroscopic surgery. In orthopedic literature postoperative shoulder stiffness is more frequently observed after open surgery than after arthroscopic surgery. Although we consider postoperative frozen shoulder a different clinical condition than other types of postoperative shoulder stiffness, we did not expect that arthroscopic surgery would be a prognostic factor for postoperative frozen shoulder. Arthroscopic surgery might violate the capsule during the arthroscopic procedure. The capsule, especially the rotator cuff interval, may be at greater risk of being traumatized during arthroscopic surgery compared to open surgery. Further research should analyze if different arthroscopic procedures and techniques will reduce the incidence of postoperative frozen shoulder.

Specialized shoulder physiotherapy was also a prognostic variable. Specialized shoulder physiotherapists were instructed to focus on the development of postoperative frozen shoulder and immediately adapt the rehabilitation program with more rest and less mobilization of the capsule. We observed during the study period that in most patients the clinical signs of frozen shoulder disappeared when the capsule was allowed more rest. If, instead, a physiotherapist proceeds with the normal rehabilitation program the condition will progress and will not respond to rest in the frozen stage, thus becoming more difficult to treat [6]. The association between the rehabilitation

Table 1 Baseline characteristics of patients with and without postoperative frozen shoulder

N (%)	Postoperative frozen shoulder 56 (11)	No postoperative frozen shoulder 449 (89)
Age (years)	47.1 (13.3)	47.5 (15.4)
Gender (*n*, %)	23 (41.1%)	264 (58.8%)
Right shoulder (*n*, %)	39 (69.6%)	268 (59.7%)
Dominant side (*n*, %)	40 (71.4%)	283 (63.0%)
Duration of symptoms (months)	18 (10;36)	18 (10;48)
Diabetes mellitus (*n*, %)	7 (12.5%)	17 (3.8%)
Thyroid disorder (*n*, %)	4 (7.1%)	18 (4.0%)
Specialized shoulder physiotherapy (*n*, %)	32 (57.1%)	35 (78.0%)
Type of operation (*n*, %)		
Subacromial decompression	6 (10.7%)	43 (9.6%)
Rotator cuff repair	12 (21.4%)	141 (31.4%)
Stabilizing procedure	18 (32.1%)	131 (29.2%)
Distal clavicle resection	10 (17.9%)	73 (16.3%)
Excision calcific deposits	3 (5.4%)	23 (5.1%)
Other shoulder operation	7 (12.5%)	38 (8.5%)
Arthroscopic surgery (*n*, %)	46 (82.1%)	322 (71.7%)
Operated before (*n*, %)	7 (12.5%)	48 (10.7%)
VAS mean	5.6 (2.0)	4.7 (2.4)
DASH	46.9 (21.0)	38,5 (19.1)
CMS	51.3 (17.2)	57.8 (18.0)
Distress (*n*, %)[a]	13 (23.1%)	99 (20.0%)
Depression (*n*, %)[a]	2 (3.8%)	37 (8.2%)
Anxiety (*n*, %)[a]	6 (11.5%)	54 (12.1%)
Somatization (*n*, %)[a]	14 (25.0%)	70 (18.4%)

Data are presented as percentage, mean (SD) or median (IQ range) in case of skewed distribution

Age, duration of symptoms (log transformed before testing), VAS mean, DASH and CMS were tested using independent sample *t* tests. VAS min and VAS max were tested using Mann–Whitney *U* tests. All other variables were tested using Chi-square tests

$P < 0.05$ is considered statistically significant

* $n = 73$ missing cases

Table 2 Univariate relationship between putative predictors and risk of developing postoperative frozen shoulder

	Odds ratio[a]	95% CI	*p* value
Gender (0 = male, 1 = female)	2.05	1.16–3.60	0.013
Diabetes mellitus (0 = absent, 1 = present)	3.63	1.44–9.19	0.006
Type of physiotherapy (0 = regular, 1 = shoulder physiotherapy)	0.38	0.21–0.67	0.001
Arthroscopic surgery (0 = open, 1 = arthroscopic)	1.81	0.89–3.71	0.100
DASH (0–100 scale)	1.02	1.01–1.04	0.005

[a] All variables except gender, diabetes mellitus, type of physiotherapy and arthroscopic surgery were treated as continuous variables. The odds ratio is the increase in odds per unit increase in the predictor

program, the physiotherapeutic treatment approaches after shoulder surgery and the development of postoperative frozen shoulder needs to be explored in future studies. In our study, longer postoperative immobilization, especially after rotator cuff repair and stabilizing procedures, did not result in higher incidences of secondary frozen shoulder. Evans et al. postulated that the development of a frozen shoulder after surgery might be an isolated pathological process, rather than a consequence of prolonged immobilization [8]. Koo et al. published a study about the benefits of a modified rehabilitation protocol in reducing the risk of postoperative stiffness after arthroscopic rotator cuff repair

Table 3 Multivariate logistic prediction model of risk of developing postoperative frozen shoulder

	Coefficient	Odds ratio[a]	95% CI
Diabetes mellitus (0 = absent, 1 = present)	1.42	4.13	1.09–12.60
Type of physiotherapy (0 = regular, 1 = shoulder physiotherapy)	−1.12	0.33	0.19–0.53
Arthroscopic surgery (0 = open, 1 = arthroscopic)	0.74	2.09	0.99–5.95
DASH (0–100 scale)	0.02	1.02	1.01–1.04

[a] All variables except DASH score were treated as dichotomous variables. The odds ratio is the difference in odds for the predictor for patients with frozen shoulder as compared to patients without frozen shoulder. Confidence intervals were bias adjusted after a bootstrap of 500 samples

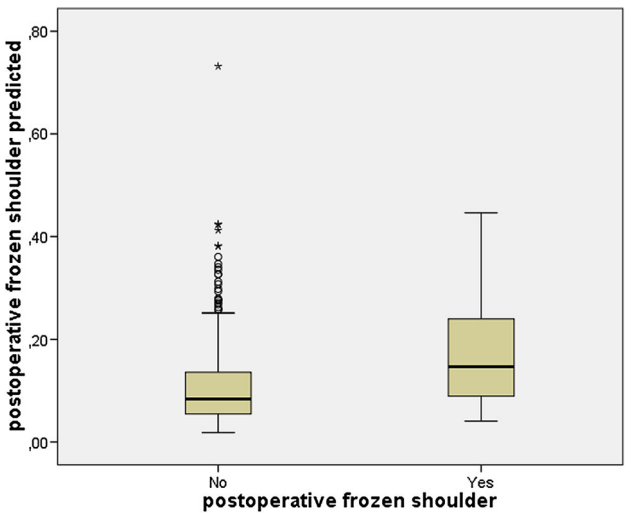

Fig. 2 Postoperative frozen shoulders were diagnosed and compared to the predicted probabilities of postoperative frozen shoulder, based on the prediction model. The *X*-axis represents the patients diagnosed clinical with the diagnosis postoperative frozen shoulder or no postoperative frozen shoulder. The *Y*-axis represents the predicted probabilities of a postoperative frozen shoulder, according to the prediction model. The *box* represents graphically 50% of the patients; the *heavy line inside the box* is the median

[24]. Patients with risk factors for postoperative stiffness, identified in a previous study by the same research group, were enrolled in a modified rehabilitation protocol. They observed that a modification of the rehabilitation protocol in at-risk patients reduces the incidence of postoperative stiffness after arthroscopic rotator cuff repair.

Frozen shoulder is a complex clinical condition with no uniform definition in literature. Both the British and the American Shoulder and Elbow Societies and the Orthopaedic Section of the American Physical Therapy Association have presented consensus definitions of frozen shoulder of postoperative frozen shoulder [14, 25, 26]. These definitions were not designed to diagnose postoperative frozen shoulder. Only one publication, by Evans et al. [8], studied the development of postoperative frozen shoulder after shoulder surgery. They used the following definition: 'all patients who developed a secondary frozen shoulder reported an initial period of good mobility following surgery, followed by a decline in movement and function.' We used their definition in our study. The description of the change in the postoperative rehabilitation period, with a decline in movement and function and worsening pain, enabled us to diagnose postoperative frozen shoulder, not only after simple arthroscopic shoulder procedures (like arthroscopic subacromial decompression), but also after shoulder procedures with immobilization or capsular or labral surgery. During the study period the definition appeared to be practical and useful in clinical practice and we were able to make the diagnosis in all patients. We have no hard evidence how well the definition of postoperative frozen shoulder is able to differentiate between postsurgical frozen shoulder and other patients with postoperative stiffness. Future studies could confirm this definition by performing an arthroscopy in all patients after shoulder surgery with histological examination to conform the absence or presence of a frozen shoulder. The follow-up period in this study was 6 months. This follow-up period is too short to observe the clinical end result after shoulder surgery but long enough to observe the development of frozen shoulder after shoulder surgery [8]. In our study period all patients with frozen shoulder got symptoms of postoperative frozen shoulder in the first three months after surgery.

Our study has several strengths. This study was a large prospective cohort study of a consecutive series of 505 patients with a low percentage of patients lost to follow-up. Patients were surgically treated by a single surgeon. All patients were rehabilitated according to strict protocols; most patients were treated by specialized shoulder physiotherapists. Because we included different types of shoulder procedures, we were able to demonstrate that postoperative frozen shoulder is a complication after various shoulder procedures. Our study has also some limitations that should be addressed before drawing conclusions. We have included a heterogeneous study population with different types of shoulder procedures. The standardized rehabilitation protocols and guidelines for mobilization were different between the shoulder procedures, with immobilization periods after rotator cuff repair and stabilizing procedures. The outcome of this study was based on

clinical examination and medical history and not confirmed by arthroscopic and histological examinations. Radiodiagnostic imaging studies, like MRI (arthrography) and ultrasonography, are primarily used to exclude other causes of shoulder pain and are of limited use in diagnosing frozen shoulder [27–29]. Postoperative measurement of the range of motion was performed by a shoulder physiotherapist and the operating orthopedic surgeon, and not by an independent researcher.

Conclusions

The incidence of postoperative frozen shoulder after shoulder surgery was 11%. Frozen shoulder was encountered after all different operative procedures. We developed a prediction model and identified four prognostic factors for postoperative frozen shoulder: diabetes mellitus, arthroscopic surgery, specialized shoulder physiotherapy and DASH score. The combination of these four variables provided a prediction rule for postoperative frozen shoulder with reasonable fit. Further research is needed to externally validate this model. After that, this prediction tool could be used in future studies to look for preventive strategies and intervention for high-risk patients of postoperative frozen shoulder after shoulder surgery.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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